



**LTI - Limno-Tech, Inc.**  
**Memorandum**

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**TO:** Doug Liden, U.S. EPA  
**FROM:** Dave Dilks  
**SUBJECT:** American Samoa Mixing Zone Review

**DATE:** 10/28/91  
**PROJECT:** PAGO  
**cc:** J. Parker, SAIC

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Attached please find a signed review from Dr. Steven J. Wright (a nationally recognized expert in mixing analyses) regarding the American Samoa mixing zone study. The most significant aspects of the review are:

- The wastefield transport modeling was appropriate, although it was not clear from the information provided how loadings from the Utulei wastewater treatment plant outfall were considered in the analysis.
- The initial dilution modeling was, for the most part, appropriate. UDKHDEN dilution predictions for the 5 cm/s current simulations were too high. The majority of simulations deal with the zero current situations; these simulations appear appropriate.
- The study is non-conservative in assuming that ambient concentrations near the edge of the mixing zone are represented by concentrations outside of the harbor. Actual ambient concentrations will likely be higher, and the true amount of dilution lower, than that assumed in the study.
- The far-field transport model used is not appropriate for simulating cases of low current.
- Attainment of water quality standard appears marginal for present loading conditions. A more careful analysis of design criteria should be provided before future expansion capacity is provided.

Feel free to call Steve or me directly with any specific questions you may have.

October 25, 1991

Doug Liden  
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Region IX  
75 Hawthorne Street  
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U.S. EPA reference: W-5-1  
Mixing Zone Application for Starkist Samoa

Review by :

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Dear Mr. Liden:

Dave Dilks from Limno-Tech has passed on to me the information that you provided in the Mixing Zone application for Starkist Samoa and Samoa Packing Company for the proposed outfall in Pago Pago harbor, American Samoa. Following are my comments from my review of the documentation provided. In general I have no major difficulties of the analyses presented for the initial dilution or the wastefield transport modeling but I discuss some specific points below. However, I believe that there are some major problems with the application of the so-called "far-field" transport model and that these will have a major impact on the interpretation of the analysis. Again more specific details are provided below. If you should wish to speak personally with me about these issues, please feel free to contact me at my University telephone number (generally afternoons after 1:30 P.M. will be best) or my home telephone (313-475-1563 after about 6:00 P.M.

**Wastefield Transport Model** - This model basically provides a long term simulation of the transport in the Pago Pago harbor accounting only for advection due to tidal motions and any fresh water inflows. The dispersion coefficients then relate to any mixing processes that occur on time scales that are small with

respect to a tidal period and were estimated by calibration of the model against observed data. The magnitudes of the dispersion coefficients as well as the trend of increasing dispersion in the outer harbor appear to be reasonable and the results of this model are probably realistic. One major question that I have is with respect to other inputs. In some of the provided figures, there is an outfall referred to as the Utulei outfall which is a wastewater treatment plant discharge. I cannot tell if the loadings from this outfall are significant or if they have been included in the analysis; these issues should be clarified. In the writeup, there is a discussion regarding nonpoint discharges and I do not know if this outfall discharge got lumped into them or not. I do not have access to the HRI(1989) report and maybe this issue is addressed in there. The second issue is that the analysis is using a depth-integrated model. The comparison against field observations is facilitated by averaging surface and at-depth water quality measurements, but the individual data indicate some vertical stratification in water quality. However, the available data are probably inadequate to justify the use of a more sophisticated approach such as using only a portion of the water column as an effective depth in the model and so I would not quarrel with the analysis but simply suggest that the actual long term transport may have a depth variation that will result in differences for a submerged waste field as compared to the existing waste discharges.

**Initial Dilution Model** - The USEPA models UMERGE and UDKHDEN were used in the feasibility study with only the latter model used in the final analysis presented in the Mixing Zone Application. In general, the application of these models seems appropriate and the only issues that I would raise are with respect to the interpretation of the results. There is some discrepancy between UMERGE and UDKHDEN in the simulations with the 5 cm/s current and it is suggested that since UDKHDEN is the more sophisticated model, it should be correct. I had thought that it was fairly common knowledge that UDKHDEN predicts higher dilutions in cases with currents than any of the other EPA plume models. In 1989, I prepared a short report for Region II that documented some problems with the existing version of UDKHDEN (*Verification of EPA Plume Model UDKHDEN* by S.J. Wright, September 30, 1989, 40 pp.) in a comparison of a fairly extensive set of laboratory and field data and suggested some minor changes to the code that would significantly improve the predictions. In running my modified code for some of the same conditions as presented in the mixing zone application, I get dilutions that are only about one-third those presented. Therefore, I would suggest

that the UMERGE results for cases with current are probably more accurate. Most of the results presented in the application are for the zero current case and my model does not give significantly different results and since these are the results generally discussed in the application, I do not have much difficulty with the general conclusions.

There is a discussion of how to interpret the dilution that I believe is incorrect and this becomes more important in the discussion of the far field model below, so I will discuss this in detail here. In the feasibility study (and elsewhere), the average dilution is defined as

$$S = \frac{C_a - C_e}{C_a - C_b}$$

in which  $C_b$  is the concentration at the end of the initial dilution process,  $C_a$  is the ambient concentration, and  $C_e$  is the effluent concentration. There is a statement that  $C_a$  ought to be taken as the concentration outside the harbor, 0.12 mg/l for total nitrogen. However, this is the concentration of the water entrained into the plumes by definition and therefore must be the local concentration (at the location of the diffuser) predicted by the wastefield transport model or some other similar approach. In general, this depends upon the long term waste loadings as well as the position of the diffuser and therefore makes the determination of ZID concentrations more complicated. There are two factors however, that should be considered. First the ambient concentration will be higher than 0.12 mg/l (TN) and therefore the required initial dilution to meet the ambient water quality standards will be greater. For example if the local ambient concentration is 0.16 mg/l TN, then the required initial zone dilution would have to be twice as much as stated in the feasibility study and permit application in order to meet the receiving water standards. Although it is not proposed to meet these standards at the end of the ZID, this result still indicates that it will be more difficult to meet ambient water quality standards elsewhere. The second factor is that most of the entrainment water is derived from depth, and this ambient water generally exhibits lower concentrations of TN and TP than the surface waters which make up the bulk of the water quality samples. This implies that a somewhat lower ambient concentration than obtained from the wastefield transport model would probably be justified.

Far-Field Transport Model - This model derives from a conceptual model presented by Brooks which allows for a scale dependent dispersion coefficient. I am assuming that the "four-thirds law" option is used in the analysis although I could not find an explicit statement to that effect. In any case, there are many statements about how conservative the model is and it is further evident that the users do not understand exactly what the implications of this model formulation is. They note that the horizontal advection must balance the lateral diffusion or else the model gives unrealistic results, therefore justifying their use of a 5 cm/s current. Actually, the problem derives from a mass consistency requirement. The total flux of nitrogen and phosphorus in the assumed flow past the diffuser must equal that arising from the diffuser itself as in

$$C W h U_a = Q_e C_e = S C_s$$

in which  $C$  is the initial concentration in the far field model,  $W$  is the initial width of the wastefield (presumably approximately equal to the diffuser length),  $h$  is the thickness of the wastefield and  $Q_e$  is the total effluent discharge. If the current speed is too small,  $C$  will end up greater than  $C_s$ , leading to the dilemma noted in the analysis. Making approximate calculations for the waste field thickness and concentration from the initial dilution results gives a result in which  $C = C_s$  for  $U_a = 5$  cm/s, thereby justifying its selection, but not for the reasons noted in the report. There are data available from which an estimate of the wastefield thickness can be made, but this really begs the issue of whether the model formulation is a valid one since the ambient current is not tied to an physical occurrence, but instead is what is needed to make the model work; low current cases simply cannot be realistically modeled with this combination of models.

Assuming that the analysis of the far field dilution at a current speed near 5 cm/s is accepted, then I think there is a problem still. On p. 25 of the mixing zone application, it is stated that near field dilutions of between 875-1250 are required. Using a more accurate estimate of ambient concentration will result in a doubling or more of these required dilutions as discussed above, so presumably the required dilution is somewhere on the order of 2000 or more. The far field transport model will yield an incremental dilution of about 3-4 (at a distance of 1300 ft from the diffuser), depending upon the specific assumptions employed, based upon hand calculations that I made with the same general analytical procedure employed in the model. This then requires an initial dilution of at least 500, which cannot be

attained in the zero current scenario with the proposed diffuser. An increase in future loadings even more severely restrains the present design, because of an increase in the ambient concentration and a decrease in the initial dilution.

The key question therefore would appear to be whether or not the zero current case is a valid condition for the initial dilution, but this is a typical approach for defining worst case conditions. Even allowing for a current but with a more appropriate analysis (UMERGE or modified UDKHDEN) makes the attainment of the water quality criteria at the edge of the mixing zone marginal, so a more careful analysis of design criteria and especially a consideration of future expansion capacity (from the point of meeting water quality standards) should be made before the permit is accepted.